Optical Properties of Aerosol Emissions from Laboratory Peat Combustion

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Introduction

Globally, organic soils and peats may store as much as 6.1 x 10^{17} g of terrestrial C, representing between one-fifth and one-third of the planet's terrestrial organic carbon (Gorham, 1994). This is approximately the same mass of C as that contained in Earth's atmosphere, despite peatlands occupying only 3% of its surface (Figure 1, Ruesch and Gibbs 2008). The contribution from smoldering combustion of organic soils to global releases of terrestrial carbon to the atmosphere may increase under scenarios of warming and drying climatic conditions (IPCC 2007).

Since the identification of optical properties of aerosol organic carbon (OC) from combustion two decades ago, an increasing number of researchers have investigated the enhanced potential of radiative forcing (RF) impacts of aerosol emissions from wildfires (e.g., See et al. 2007). These studies have identified smoldering as a major contributor of brown carbon (BrC) aerosol compared to flaming combustion (e.g. Hadden 2011).

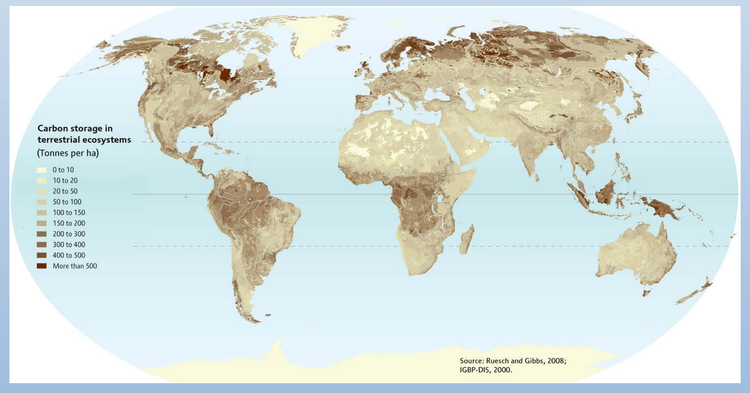
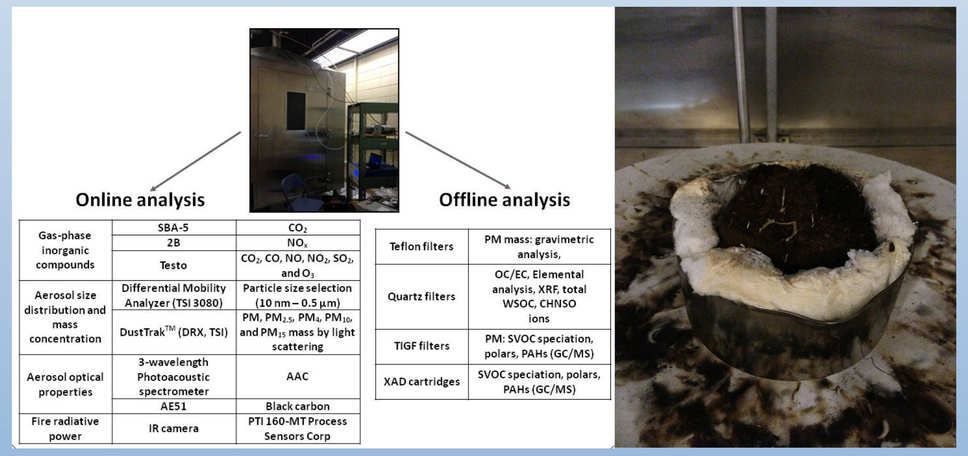


Figure 1: (left) Storing a third of global terrestrial carbon, peats emit large amounts of particle mass when they are consumed in ground fires (right). Impacts of these aerosols on global climate are unknown.

Additionally, the research on aerosol emissions from biomass burning has focused on combustion in aerial fuels and to some extent in duff fuels, but not on peat or organic soils. These latter fuels are likely to contribute even higher amounts of aerosol BrC than duff during smoldering, due to less efficient combustion resulting from their moisture and mineral content and packing density. There already exists much uncertainty in our understanding of the contribution of biomass burning aerosols to RF (IPCC 2007), but the lack of attention to this contribution from peat fires, despite their large emissions and potential for increased occurrence, creates a striking knowledge gap with respect to future global climate change.

Methods

Samples of peat soils from four locations representing the various biomes in which these soils occur (Siberia, Russia, and Alaska, USA, representing boreal and arctic ecosystems, and two locations in Florida, USA, representing temperate and subtropical ecosystems), were burned in the 8m^3 DRI combustion facility (Figure 2, left), at moisture levels approximating those found during droughts and under which peat soils will support combustion. Aerosol emissions were characterized for optical properties with three-wavelength photoacoustic spectrometer and nephelometer (Moosmüller et al. 2009) including online and offline smoke analysis.



Gas-phase inorganic compounds	SBA-5	CO_2
	2B	NO_x
	Testo	CO_2, CO, NO, NO_2, SO_2, and O_3
Aerosol size distribution and mass concentration	Differential Mobility Analyzer (TSI 3080)	Particle size selection (10 nm – 0.5 µm)
	DustTrak™ (DRX, TSI)	PM, $PM_{2.5}$, PM_4, PM_{10}, and PM_{15} mass by light scattering
Aerosol optical properties	3-wavelength Photoacoustic spectrometer	AAC
	AE51	Black carbon
Fire radiative power	IR camera	PTI 160-MT Process Sensors Corp

Teflon filters	PM mass: gravimetric analysis,
Quartz filters	OC/EC, Elemental analysis, XRF, total WSOC, CHNSO ions
TIGF filters	PM: SVOC speciation, polars, PAHs (GC/MS)
XAD cartridges	SVOC speciation, polars, PAHs (GC/MS)

Figure 2: The DRI biomass combustion facility (*left*) also shown the online and offline aerosol analysis schemes. Samples were burned in insulated containers (*right*) to simulate field conditions in which surrounding peat soils provide insulation, trapping heat and gasses near the site of smoldering combustion.

Data Analysis

We compared optical properties of peat samples collected in three biomes at two different moisture levels to determine whether peats from across multiple biomes differed in the optical properties of their emissions. Two fuel moisture levels were used in our work to enable us to determine whether peat source or fuel moisture content was more important to emissions optical characteristics. Aerosol absorption and scattering coefficients, measured at three wavelengths (405, 532, and 870 nm) were analyzed for single scattering albedo (SSA) and absorption Ångström coefficients (AAC) (405-870 nm). While SSA was comparable to that of emissions from other smoldering fuels, AAC was substantially higher. Moisture content also played an important role; AAC was higher for lower moisture levels for all peat samples. Florida lake peat (at 10% moisture level) exhibited the highest AAC value (~7.2).

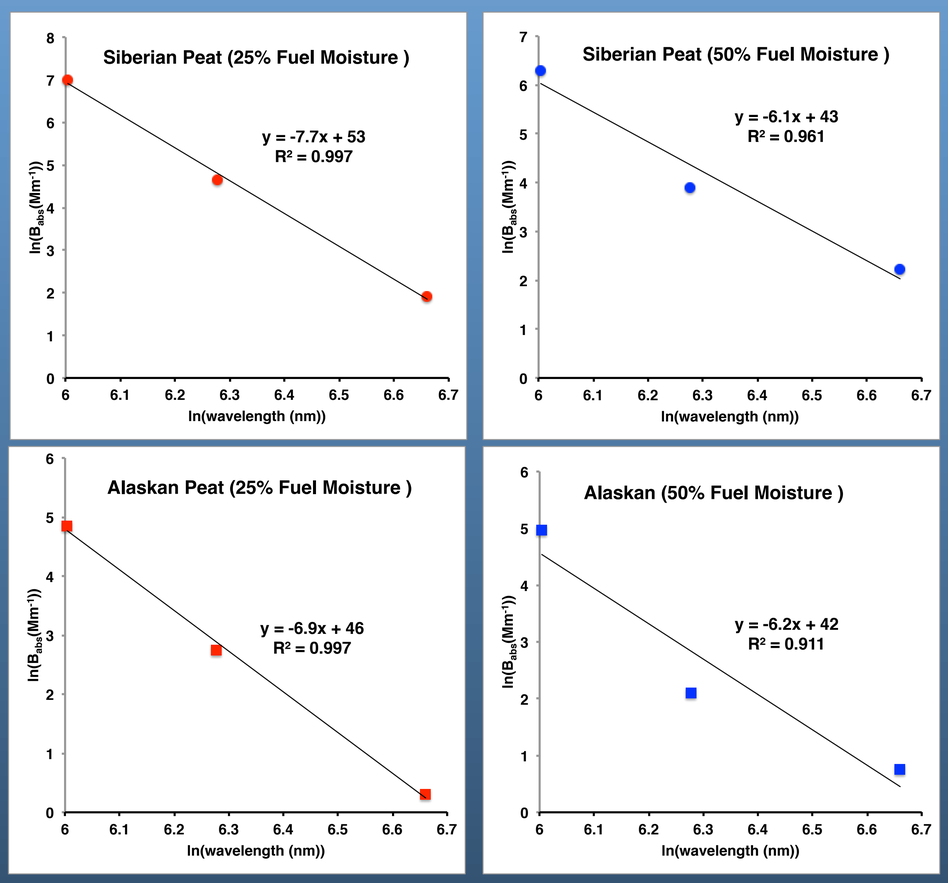
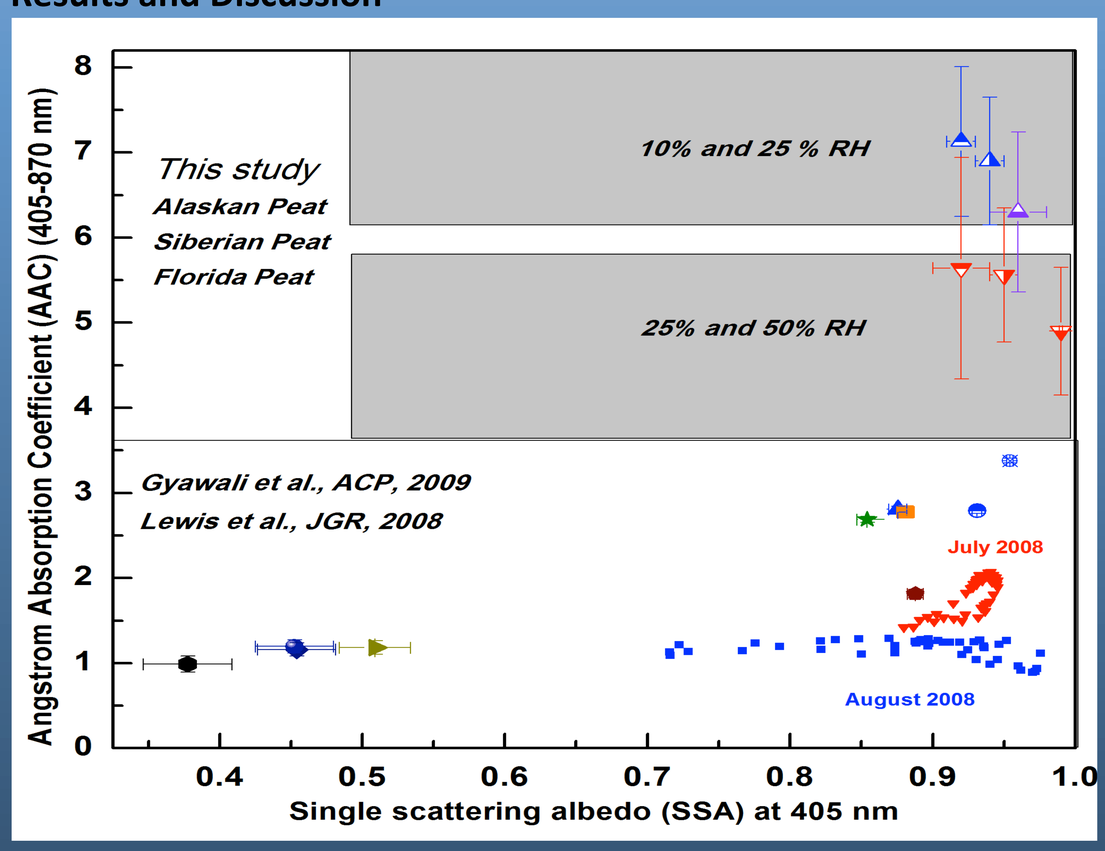


Figure 3. Aerosol absorption coefficients as function of wavelength in a log-log plot. The Absorption Ångström Coefficient (AAC) is the negative slope. Note the larger curvature at higher fuel moistures.

Peat sample	Fuel Moisture (%)	MAC (m^2g^{-1})			AAC			SSA		
		405 nm	532 nm	781 nm	405/532 nm	405/781 nm	532/781 nm	405 nm	532 nm	781 nm
Florida Lake	10	-	-	-	8.70	8.12	7.71	0.92	0.99	1.00
Florida Swamp	25	0.32	0.03	0.004	8.46	6.42	4.97	0.92	0.99	1.00
Siberian	25	0.27	0.02	0.002	8.65	8.01	7.55	0.93	0.99	1.00
	50	0.24	0.02	0.002	8.69	6.05	4.17	0.94	0.99	1.00
Alaskan	25	0.12	0.01	0.001	7.66	7.15	6.78	0.97	0.99	1.00
	50	0.19	0.01	0.003	10.79	6.76	3.89	0.96	0.99	1.00

Table 1. Mean organic mass-normalized absorption cross-section(MAC), absorption Ångström coefficients (AAC) and single scattering albedo (SSAA) at 405, 532, and 781 nm for various peat samples at 10%, 25%, and 50% moisture levels.

Results and Discussion



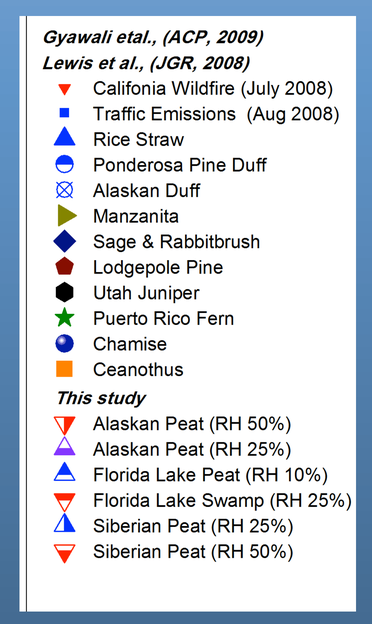


Figure 5: Optical characteristics of peat emissions (top) compared with those of other fuels.

Compared with reported values for many other common wildland fuels, emissions from the four peats measured in this study displayed similar values for single scattering albedo, with values in the 0.9-1.0 range at 405nm (Figure 5). However, observed values for absorption Ångström coefficients (405-870 nm) were substantially higher for peats than for other fuels. Furthermore, our observations appear to indicate that as moisture content of a peat sample decreased, AAC values for their emissions increased.

Conclusions

As changes to climate and land-use patterns result in increasing desiccation to peatlands worldwide, wildfire activity is widely expected in increase in these areas. However, one unforeseen consequence to scenarios of peatlands burning at decreasing moisture levels is the potential change to optical characteristics of their emissions. This preliminary study appears to suggest that:

1. Despite the geographical difference of the peat samples, smoke aerosols from all three types of peat show strong wavelength dependence of light absorption.
2. Wavelength dependence of aerosol light absorption of peat smoke aerosol was found to decrease with increasing moisture content.
3. All peat smoke exhibited high AAC, mass absorption coefficients (MACs) were found to be quite low; in the range 0.01-0.03 m^2g^{-1} at 532 nm, similar to values of 0.029-0.031 m^2g^{-1} for humic-like substances (Hoffer et al., 2006).

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